Published in final edited form as:

J Speech Lang Hear Res. 2007 February ; 50(1): 161–176.

Conceptual Organization at 6 and 8 Years of Age: Evidence From the Semantic Priming of Object Decisions

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Abstract

Purpose— The purpose of this study was to examine children's knowledge of semantic relations.

Method— In Experiment 1, the 6-year-olds, 8-year-olds, and adults participated in an object decision task. Participants in the primed group made object decisions in response to primes that were related taxonomically, thematically, or perceptually to the target objects. Those in the unprimed group made decisions about the same stimuli without the benefit of primes. In Experiment 2, the children in the primed group explained the taxonomic and thematic relations between the prime–target pairs used in Experiment 1.

Results— In Experiment 1, the strength of semantic relations did not vary with type or age, as taxonomic priming was as strong as thematic priming and the degree of priming did not reliably differentiate the 3 age groups. Differential priming effects between taxonomic and perceptual conditions, the former hastening and the latter slowing responses, suggested that the relation binding object concepts into taxonomies was not reducible to common physical features. In Experiment 2, the 6-year-olds had more difficulty describing taxonomic than thematic relations, whereas the 8-year-olds described both with ease.

Conclusions— Contrary to the shift hypothesis, taxonomic and thematic relations-structure concepts in children as young as 6 and into adulthood. In accord with the performance hypothesis, 6-year-olds' representations of taxonomic relations are fragile and vulnerable to high task demands.

Keywords

semantic; priming; thematic; taxonomic; development

Adults organize object concepts in rich and varied ways. Taxonomies are one such organizational structure; themes are another. Taxonomies are categories of objects that share a common essence. These may be natural kinds (e.g., *pine tree* and *oak*) or artifacts (e.g., *pencil* and *crayon*). Objects in a given taxonomy are likely to be similar in perceptual features (Medin & Ortony, 1989), and young children use perceptual features to extend labels to other objects in a given taxonomy (Landau, Smith, & Jones, 1988). However, mature taxonomic knowledge is not merely perceptual, it includes understanding of biological essence (in the case of natural kinds; Carey, 1988, 1991) and functional essence (in the case of artifacts; Springer & Keil, 1991). Objects related by themes do not share an essence, rather they are bound by an event schema (Shank & Abelson, 1977). For example, the objects *pencil* and *paper* may be part of a classroom schema, as are *teacher*, *student*, *desk*, and *computer*. Relations that bind objects into themes include spatial (e.g., *paper* and *desk*), causal (e.g., *student* and *pencil*), and functional (e.g., *pencil* and *paper*; Lin & Murphy, 2001).

The child's acquisition of these conceptual structures is a topic of long-standing debate. Inhelder and Piaget (1964) observed preschoolers sorting objects into categories according to spatial (thematic) relations rather than perceptual (taxonomic) similarity. Preschoolers also demonstrate preferences for thematic relations during forced-choice matching tasks (Smiley & Brown, 1979) and a variety of recognition and naming tasks (Daehler, Lonardo, & Bukatko, 1979; Fenson, Vella, & Kennedy, 1989; Scott, Greenfield, & Urbano, 1985; Scott, Serchuk, & Mundy, 1982). However, by 8 years of age and into adulthood, taxonomic relations are preferred in such tasks, leading to the hypothesis that conceptual development is characterized by a thematic to taxonomic shift (see Lin & Murphy, 2001, for a review).

Nevertheless, other evidence suggests that the shift may represent something less than a dramatic cognitive restructuring. Preschoolers demonstrate flexible categorization strategies, switching from thematic to taxonomic categories when context mandates (Blaye & Bonthoux, 2001; Nguyen & Murphy, 2003). In forced-choice matching tasks that include novel noun labels (e.g., this is a *dax*, find another *dax*), preschoolers tend to choose taxonomically rather than thematically (Waxman & Gelman, 1986). When asked contrast questions (e.g., "This is not a plant, it's a _____?"), preschoolers demonstrate knowledge of superordinate (e.g., *animal*), basic (e.g., *dog*), and subordinate (e.g., *collie*) levels of taxonomies (Elbers & van Loon-Vervoorn, 1998). Even preschoolers with language impairments demonstrate the ability to name at multiple levels of object taxonomies following contrast questions (McGregor & Waxman, 1998).

In response to data of this sort, several weaker versions of the shift hypothesis have been put forward. For example, Scott and colleagues (Scott et al., 1982, 1985) hypothesized a developmental progression in the accessibility of thematic and taxonomic relations. They report that, in minimally demanding tasks (e.g., asking a child to pair a picture of a tiger with either a picture of a zebra or a picture of a balloon), even 3-year-olds are highly accurate at identifying taxonomic relations. When task demands are increased by asking the children to justify their pairings, performance falls, and this performance decline is greater for taxonomic relations than for thematic ones. The more abstract nature of taxonomic concepts is proposed as the basis for this vulnerability. Thus, one weak version of the shift hypothesis is that both thematic and taxonomic relations are present from an early age, but taxonomic relations, being more abstract, are more fragile in their representation and hence more prone to performance declines when task demands are high. We refer to this as the *performance hypothesis*.

Indirect support for the performance hypothesis comes from numerous reports that both children and adults vary in their dependence on thematic and taxonomic systems according to task requirements and instructions (Osborne & Calhoun, 1998; Walsh, Richardson, & Faulkner, 1993; Waxman & Namy, 1997). Additionally, understanding of task expectations may change with education (Luria, 1976). For example, adults who are uneducated make fewer taxonomic choices than children who have completed the sixth grade (Sharp, Cole, & Lave, 1979). This explanation fits well with children's experiences between 5 and 8 years: The age range of the purported shift coincides with the first 3 years of formal reading and academic instruction.

A second weak form of the shift hypothesis is that children may represent both thematic and taxonomic relations from an early age, but that the latter are limited in type for some time. Lucariello, Kyratzis, and Nelson (1992) distinguished three horizontal relations among objects in a taxonomy, conventional superordinate, conventional subcategory, and slot-filler subcategories. Artifacts belong to a conventional superordinate category if they share general functional features (e.g., *shoes* and *robes* are both things to wear). Artifacts belong to a conventional subcategory if they share a constrained function (e.g., *shoes* and *slippers* are both things to wear on the feet). Slot fillers also share a constrained function, but, additionally, they hold a spatiotemporal association (e.g., *robes* and *pajamas* are both things to wear on the body

at bedtime). Slot fillers can be considered a special subset of thematic associates as they entail event-based relations, but they also meet criteria for taxonomic membership. Lucariello et al. argued that slot fillers serve as a developmental basis for growth from strictly thematic conceptual organization to a more flexible organization that entails both thematic and taxonomic relations. We refer to this particular weak version of the shift hypothesis as the *slot-filler hypothesis*. In support of the slot-filler hypothesis, Lucariello and colleagues reported 4-year-olds to demonstrate knowledge of taxonomic relationships that was largely limited to slot fillers during semantic fluency, word association, and match-to-sample tasks; whereas 7-year-olds demonstrated more varied forms of taxonomic knowledge on these same tasks.

In summary, the strong version of the thematic–taxonomic shift hypothesis holds that children represent thematic relations very early in development and come to represent taxonomic relations only by the school years. Roughly between the ages 5 and 8 years, the conceptual system undergoes a restructuring such that by 8, and into adulthood, taxonomic relations dominate. Two weaker versions of the shift hypothesis, the performance hypothesis and the slot-filler hypothesis, hold that both thematic and taxonomic relations structure concepts from an early age but that taxonomic structures are more fragile or more limited in type, respectively. With development, taxonomic structures become more robust (less susceptible to task demands) or more varied (less restricted to taxonomies that can participate in slot-filler roles). Note that the performance hypothesis and the slot-filler hypothesis are not mutually exclusive.

Priming

Priming paradigms are an ideal method of testing children's knowledge of semantic relations without requiring the child to consciously articulate that knowledge. Two priming studies have addressed the development of children's taxonomic and thematic concepts. McCauley, Weil, and Sperber (1976) studied semantic priming in 6- and 8-year-olds. These children participated in a picture naming task in which prime–target pairs were (a) high thematic (associative)¹–high taxonomic (categorical; e.g., *cat–dog*), (b) high thematic–low taxonomic (e.g., *bone–dog*), (c) low thematic–high taxonomic (e.g., *lion–dog*), or (d) low thematic–low taxonomic (e.g., *airplane–dog*). Thematic priming was demonstrated in both groups, whereas taxonomic priming was demonstrated only by the 8-year-olds. In both cases, the prime served to facilitate the speed of picture naming. Nation and Snowling (1999) also found an effect of developmental ability on priming behavior when they asked 10-year-old normal readers and 10-year-old poor readers to make auditory lexical decisions. Both groups responded more quickly to thematic primes (e.g., *beach–sand*; *hospital–doctor*) than to an unrelated baseline. However, the normal readers, but not the poor readers, demonstrated priming in response to taxonomic, nonthematic primes (e.g., *cow–goat*).

Though these data are consistent with the shift hypothesis, the weaker performance hypothesis cannot be ruled out conclusively. Both tasks involved a linguistic processing load in that naming or judgment of words was required. As such, one cannot be certain whether the apparent difficulty with taxonomic categories was exaggerated by the high task demand, as predicted by the performance hypothesis. On the other hand, the particular stimuli used in these studies may have limited the manifestation of difficulties with taxonomic relations. Some of the stimuli used in the taxonomic conditions were slot fillers (e.g., *cats* and *dogs* are both household pets; *cows* and *goats* are both found on the farm). Therefore, one cannot be certain whether the more

¹*Taxonomic*, a term frequently used in the developmental literature, is equivalent to the term *categorical*, as it is frequently used in the priming literature. *Thematic relations*, also a term encountered in the developmental literature, are a subset of relations termed *associative* in the priming literature. Associative pairs are those that are formed when one word automatically elicits another word. Therefore, associative relations include thematic relations (e.g., *scissors* and *paper*), but may also include taxonomic relations (e.g., *dog* and *cat*). To be consistent with the developmental literature, we use the terms thematic and taxonomic in the current study, and we have taken care to ensure that these terms accurately describe the prime–target pairs we created.

mature participants in these studies would have demonstrated taxonomic priming with items that related solely by category and not by schema. Finally, it is difficult, on the basis of these studies, to attribute “true” taxonomic priming to the participants because the taxonomic stimuli frequently shared perceptual features. Consider that *cats* and *dogs* look very similar, as do *cows* and *goats*. Did the priming behavior of the older participants reflect a shift to mature semantic knowledge or was it merely an effect of perceptual priming? The problem is especially pertinent given that perceptual similarity is thought to feed children’s conceptual learning, but that conceptual knowledge itself cannot be reduced to perception (Mandler, 1992).

The Current Study

The general aim of the current study was to test the strong form of the shift hypothesis (Experiment 1) and, as an alternative, the performance hypothesis (Experiment 2). We did not directly test the slot-filler hypothesis, but ruled it out as an interpretation for the current data by careful selection of stimuli.

Experiment 1

In Experiment 1, we reasoned that if the thematic–taxonomic shift is a developmental phenomenon reflecting conceptual restructuring, then the shift should be apparent even in a task that (a) reduces performance demands and (b) excludes taxonomic exemplars that are also slot fillers. That is, participants who are just beginning the shift should demonstrate weaker knowledge of taxonomic relations than thematic relations. To test this prediction, we used an object decision task that involved thematic and taxonomic primes. The participants were 6-year-olds, children who should be in the early stages of the thematic–taxonomic shift, and 8-year-olds, children who should be in the late stages of the shift. Adults were also used as a comparison group as they should demonstrate a well-engrained dominance of taxonomic conceptual structure, should that dominance exist.

During object decision tasks, participants are asked to judge as quickly as possible whether a pictured target is a real object or a nonobject (i.e., fantasy). The task involves structural but not semantic processing (Gerlach, Law, Gade, & Paulson, 2000); thus, in and of itself, object decision cannot demonstrate anything about semantic knowledge. However, object decision is subject to top-down influences (Marr, 1982; Riddoch & Humphreys, 2001); therefore, one can overlay semantic primes on the task and observe their effects. If the speed or accuracy of object decision is changed under semantic priming conditions, the child’s knowledge of the semantic relations is revealed. Therefore, primed object decision was an ideal task for testing the shift hypothesis.

To date, reports of children’s performance in semantically primed object decision tasks are rare. Brouwers and colleagues (2001) compared semantic priming and repetition priming in a group of 6- to 12-year-olds with language deficits secondary to HIV infection. The children did demonstrate priming as evidenced by faster object decisions in the semantically related condition than in an unrelated baseline condition. However, the prime–target pairs were not described, so it is impossible to determine the relative saliency of the thematic and taxonomic relations. The current study will remedy this gap.

Because primed object decision reveals evidence of semantic knowledge without requiring lexical retrieval or overt expression of that knowledge, it holds an advantage over the primed picture naming task of McCauley et al. (1976) and the primed lexical-decision task of Nation and Snowling (1999). These tasks required lexical retrieval and therefore involved a performance demand that may have resulted in an underestimation of the conceptual organization of the younger or developmentally less able participants. No task is free of

performance demands; however, a nonverbal paradigm like object decision may enable a cleaner test of the shift hypothesis.

The usefulness of the primed object decision task was further enhanced by adding a perceptual priming condition to Experiment 1. Assuming cascade processing (Marr, 1982; Riddoch & Humphreys, 2001), we reasoned that the effects of shared perceptual features (in this case shape) and shared semantic features (in this case taxonomy) on object decision would materialize in different time courses, with shape processing beginning earlier than access to taxonomic information. Therefore, including a perceptual condition allowed a disentangling of perceptual from taxonomic relatedness. If the influence of the taxonomic primes is truly semantic, then shape and taxonomy should produce different effects when the same time parameters are used. If the influence of taxonomic primes reduces to a low-level perceptual effect, then shape and taxonomy should affect object decisions similarly.

In summary, Experiment 1 involved three developmental levels—6-year-olds, 8-year-olds, and adults—as well as two types of semantic priming relations—taxonomic and thematic. Roughly half of the participants in each age group made object decisions following primes. To ascertain priming effects, the speed of their decisions was compared with those of the remaining participants, who made object decisions without benefit of primes.

We used this paradigm to test the shift hypothesis:

- Given the hypothesized thematic–taxonomic shift, we predicted a greater priming effect of thematic relations than taxonomic relations. Furthermore, effects should vary such that the difference between thematic and taxonomic priming is more pronounced for the 6-year-olds than for the 8-year-olds and least pronounced for the adults.
- To ensure that any effects of taxonomic primes were conceptual, not merely perceptual, the effects of taxonomic and perceptual primes on object decisions were compared. Given the hypotheses that (a) members of taxonomic categories share a common essence, not just common perceptual features; (b) semantic categories exert a top-down influence on object decisions whereas perceptual primes exert a bottom-up influence; and (c) semantic features will be activated after perceptual features, we predicted different effects of these two priming types.

Experiment 2

To anticipate the results of Experiment 1, we found evidence of conceptual priming; however, thematic primes did not result in greater degrees of priming than taxonomic primes. To enhance our interpretation of this null result, a second experiment was conducted. The task in Experiment 2 required conscious reflection and verbalization of conceptual relations, thereby representing a higher task demand than that required by the primed object decision task of Experiment 1. Experiment 2, therefore, allowed a test of an alternative to the shift hypothesis, the performance hypothesis. Furthermore, it permitted replication of the purported shift as obtained by previous investigators who used cognitively demanding tasks.

Experiment 1

Method

Participants—Seventy-three participants were assigned to various age and priming groups. In the primed group were 6 girls and 8 boys who were 6-year-olds ($M = 6$ years, 5 months), 8 girls and 7 boys who were 8-year-olds ($M = 8$ years, 4 months), and 10 women and 5 men who were young adults (18–35 years). The participants in the unprimed control group were 5 girls and 4 boys who were 6-year-olds ($M = 6$ years, 4 months), 6 girls and 5 boys who were 8-year-olds ($M = 8$ years, 4 months), and 10 women and 1 man who were young adults (18–35 years).

The unequal groups reflect timing of participant recruitment and random assignment, not attrition.

All participants were monolingual English speakers from middle-to-upper socioeconomic classes as indicated by parental occupations or their own occupations in the case of the young adults. All had normal or corrected-to-normal vision; none had any history of or current concerns about language development, according to parent report or self-report in the case of the young adults. The children received either a small toy or \$5 for their participation. The adults did not receive payment.

Stimuli

Pictures of 72 concrete objects were chosen for the real object conditions of the primed experiment. All object names were likely to be familiar to 6-year-olds as indicated by acquisition norms (Carroll & White, 1973; Gilhooly & Logie, 1980; Morrison, Chappell, & Ellis, 1997). All real object stimuli were black and white pictures obtained from *Master Clips Vector Art* 1996 or from *Windows Art Explosion: 600,000 Images* 1998.

The taxonomic condition consisted of nine pairs of pictured objects, each pair representing a different superordinate category. The use of superordinate as opposed to basic level categories enabled comparison between this study and most previous studies of conceptual development (see Nguyen & Murphy, 2003, for a review). Superordinates held the further advantage of allowing some disentangling of shared semantic and physical features (e.g., a *piano* and a *guitar*, members of the superordinate category *instruments* are less similar physically than are *collies* and *poodles*, members of the basic level category *dogs*).

To ensure that there existed a strong taxonomic relation within the pairs, a taxonomic relatedness judgment task was given to 10 adults. They were asked to rate the taxonomic relation within selected pairs on a scale from 1 (*very related*) to 7 (*very unrelated*). The mean taxonomic relatedness rating score for the pairs ultimately chosen was 1.49 ($SD = 0.40$), and no relation was scored above 2.

The thematic condition consisted of nine pairs of pictured objects with temporal, spatial, or causal relations. These pairs were used in published studies (Lupker, 1988; Marshall & Cofer, 1970; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Postman & Keppel, 1970), and, in some cases, the publications included association norms. Because association norms were unavailable for some pairs, a thematic-associate judgment task was given to a new group of 10 adults. They rated the strength of the thematic relation within the pairs on a scale from 1 (*highly associated*) to 7 (*not associated*). The mean thematic relatedness rating score for the pairs ultimately chosen was 1.33 ($SD = 0.35$), with no pair scoring more than 2. To avoid selection of slot fillers (Lucariello et al., 1992), pairs that received both high taxonomic and thematic relatedness ratings (e.g., *pen-pencil*) were not included in either the taxonomic or the thematic conditions.

Stimuli for the perceptual condition were nine pairs of pictured objects that were not related semantically, but were highly similar in shape. Twenty adult raters judged the strength of the shape relation within pairs on a scale from 1 (*highly similar*) to 7 (*highly dissimilar*). For the stimuli ultimately selected for the perceptual condition, the mean rating score was 1.73 ($SD = 0.23$), with no pair scoring more than 2.

The unrelated condition consisted of nine pairs of pictured objects that held no relation. These pairs were rated 5–7 on both the thematic and the taxonomic relatedness scales. The grand mean of thematic and taxonomic relatedness ratings for the unrelated pairs ultimately chosen

was 6.2 ($SD = 0.46$). The names of the prime–target pairs in each real object condition are listed in Appendix A.

To obtain a 1:1 real object-to-nonobject ratio, an important criteria for avoiding an expectancy response, 72 black and white pictures were also used in the nonobject condition. These were either chosen from Kroll and Potter (1984) or created by the authors. To ensure that the non-objects and the real objects were equivalent in visual complexity, a group of 10 adults rated the visual complexity of all the stimuli using a scale of 1 (*very simple*) to 7 (*very complex*). The overall visual complexity means for the real objects and nonobjects were 3.59 and 3.61, respectively, $t(1, 42) = 0.977$, *ns*. Examples of the picture stimuli from each real object condition and examples of the nonobjects are displayed in Appendix A.

Procedure

Design—Because primed object decisions have been rarely used with children, it was not clear whether repeated exposure to the same stimuli in primed and unprimed conditions would influence the responses of the individual over the course of the experiment. Therefore, we chose a between-subjects design for the experiment (see Palmer, 1975, for an example). Participants in the primed group made object decisions (*real or not real*) following primes that were related taxonomically, thematically, or perceptually to the target object. Their reaction times (RTs) were compared with those of participants in the unprimed group who made decisions about the same target objects but without benefit of primes. The primed participants also made object decisions following unrelated primes. This allowed us to compare their baseline rate of responding to that of the unprimed group to ensure that they were well matched in general ability to respond quickly. Finally, all participants made decisions about as many nonobjects as real objects. These were not analyzed but rather were included to make meaningful the decision between real and not real. So that no pattern could be discerned, nonobjects were primed (preceded) by non-objects and real objects equally often.

Instructions—Participants were tested individually at the Northwestern University Child Language Laboratory. Adult participants were told that objects would be presented on the screen, and that they were to decide if the gray-bordered objects (for the primed group) or all objects (for the unprimed group) were real by pressing, with their dominant index finger, the 4 key on the number keyboard if “yes,” or the 6 key if “no.” After a practice set of eight prime–target pairs that represented the different conditions used in the study, the participant completed the experiment proper. The session lasted approximately 20 min.

To ensure that the children understood the procedure, each child first sorted as real or not real a trial set of hard copy pictures. The examiner provided feedback and repeated the trial until performance was perfect. Then the child was told that, during the computer task, objects would be presented and that the task was to decide if the gray-bordered objects (for the primed group) or all objects (for the unprimed group) were real or not real. If real, the child pressed the key with a happy face (the 4 key); if not real, the sad face (the 6 key). The child could place a sticker on the index finger to cue the correct finger for the task.

Once the child understood what to do, he or she began the trial set at the computer. Breaks were provided after a block if any child requested one or if the examiner noticed decreased attention. The sessions lasted about 30 min for each child.

Experimental script—Order of stimulus presentation was pseudorandomized with the following constraints: Real objects from the same semantic category were not presented consecutively (e.g., the taxonomic pair, *bus–airplane*, was not followed by the thematic pair, *bicycle–helmet*), and trials involving real objects (or nonobjects) were not presented more than five times consecutively. Each picture was presented for 500 ms with an inter-stimulus interval

of 500 ms, making the stimulus onset asynchrony (SOA) 1,000 ms. The intertrial interval was 500 ms (see Lupker, 1984, for a discussion of these values). RTs were measured from the onset of the target picture to the time the response key was pressed. The experimental script was set up with SuperLab Pro 1.74, and run on a Power Macintosh G3 with a 21-in. monitor and standard keyboard. SuperLab recorded accuracy of responses and RTs in milliseconds. The procedure is illustrated in Appendix B.

Perception check—Misperception of the stimuli (e.g., child viewed a *potato* as a *sponge*) would obscure priming effects on speed of processing. Therefore, immediately following the priming task, we asked each child to name all of the prime and target stimuli as they were presented one per page of a notebook. We refer to this as the *perception check*. The child had to answer “not real” to be credited for any nonobject. Correct answers for the real objects in the taxonomic condition were either the intended name or the name of a member of the same taxonomic category, given that logically either could produce priming. Similarly, the intended name (e.g., *road*), or a synonym (e.g., *street*) that held a legitimate relation with the target (e.g., *car*), was considered correct in the thematic condition. Correct answers for the real objects in the unrelated condition were either the intended name or any other real object name that was unrelated to the target, given that the same amount of priming (or lack of priming) should result from either. Any misperceived items were then omitted from the relevant child’s data before RTs were calculated.

Data cleaning—Outliers in the RT distribution were cleaned. This procedure is recommended to reduce the possibility that effects may be located entirely within the extended tail characteristic of RT responses (Ratcliff, 1993; but see Ulrich & Miller, 1994, for a different approach). Outliers that were less than 200 ms were removed from the data set because this value represents the minimal RT of a motor response to simple visual stimuli (Welford, 1980). Outliers that were longer than 6,000 ms for children or longer than 3,000 ms for adults were replaced by the condition mean plus two standard deviations. These long latencies were viewed as problematic because they may reflect strategic processing or a lapse in attention. Nevertheless, these were long responses and replacement with plus two standard deviations was a more conservative approach than omitting them. For each individual, the data were further cleaned by removal of any stimuli that yielded object decision errors or, for the children, naming errors during the perception check.

Results

After data cleaning, the data remaining to be analyzed represented 92.1%–96.27% of the original data set, depending on age and priming group. Details appear in Table 1.

Accuracy—RT is likely to be more sensitive to priming effects than accuracy. However, we analyzed accuracy levels as a preliminary step as doing so served as a check on the children’s comprehension of the object decision task. Furthermore, with accuracy data available, we could check for trade-offs between speed and accuracy should semantic primes enhance speed of processing.

Overall accuracy rates were high (Table 2), indicating that even the 6-year-olds could identify the objects as real or not real at substantially better than chance levels. That said, there was a main effect of age, $F(2, 69) = 13.88, p < .00001, f = .45$, such that 6-year-olds were less accurate than 8-year-olds ($p = .02$) and adults ($p = .0002$), whereas the 8-year-olds and adults did not differ ($p = .19$).

Priming also affected accuracy, $F(1, 69) = 30.87, p < .00001, f = .5$, such that the primed group was more accurate than the unprimed group. The main effects of age and priming group were

qualified by a two-way interaction, $F(2, 69) = 7.15, p = .0015, f = .333$, because priming was measurable for the 6-year-olds (6 unprimed compared with 6 primed: $p = .0001$) and 8-year-olds (8 unprimed compared with 8 primed: $p = .003$), but not for the adults (adult unprimed compared with adult primed: $p = .99$).

There were also differences in accuracy between conditions, $F(3, 207) = 3.94, p = .009, f = .229$, such that performance was higher in the thematic condition than in the taxonomic condition ($p = .01$). Note that this main effect does not say anything about the relative accessibility of thematic and taxonomic relations as the effect is driven, in part, by the performance of participants in the unprimed group, those responding to objects without exposure to any thematic or taxonomic relations.

Finally, there was a three-way interaction between age, priming group, and condition, $F(6, 207) = 2.45, p = .03, f = .253$. As illustrated in Figure 1, this interaction reflected the prominence of taxonomic priming among the 6-year-olds. Six-year-olds in the primed group performed significantly better than those in the unprimed group in the taxonomic condition ($p = .007$), but not in any other condition ($ps > .05$). There were no significant priming effects by condition for either the 8-year-olds or the adults.

From these data, we conclude that the children understood the task and that accuracy measures were sensitive to priming in children but not in adults, whose accuracy levels were at ceiling. Near-ceiling level performance among the 8-year-olds also limited chances to determine whether degree of priming varied with type of prime. After this preliminary step, we analyzed RT in anticipation of a more sensitive measure of priming.

RTs in the unrelated condition—To ensure that the primed and unprimed groups were equivalent in their baseline RTs, we compared mean RTs in response to items in the unrelated condition (Table 3). An ANOVA with age and priming group as between-subjects variables revealed a main effect of age, $F(2, 69) = 47.20, p < .00001, f = .75$. Six-year-olds were significantly slower than 8-year-olds ($p = .002$) who were in turn significantly slower than adults ($p = .0001$). RTs for primed and unprimed groups in the unrelated conditions did not differ statistically, $F(1, 69) = 2.20, p = .14$; however, given $p = .14$, it cannot be said that the two groups had equivalent baseline RTs (see Mervis & Robinson, 1999). Furthermore, RTs were fairly variable within groups (see standard deviations in Table 3). Therefore, to be conservative, we adjusted each individual's RT in the related conditions by his or her baseline RT in the unrelated condition by deriving a difference score. For example, the RTs analyzed in the taxonomic condition were computed with the formula $\text{mean RT}_{\text{taxonomic}} - \text{mean RT}_{\text{unrelated}}$. This adjustment was made for both primed and unprimed groups.

Degree of semantic priming—Figure 2 presents the baseline-adjusted reaction times by age, priming group, and semantic priming condition. These data were tested via a mixed-model ANOVA, with age (6, 8, adult) and priming group (primed, unprimed) as between-subjects variables and condition (taxonomic, thematic) as within-subject variables. There was a main effect of priming group, $F(1, 69) = 6.10, p = .02, f = .25$, as the primed group made faster judgments than the unprimed group. There was no main effect of age group, $F(2, 69) = 0.13, p = .88$, nor was there an effect of condition, $F(1, 69) = 1.03, p = .31$, nor an interaction between age and condition, $F(2, 69) = 1.38, p = .26$, nor between age and priming group, $F(2, 69) = 0.54, p = .58$, suggesting that the pattern of priming was similar for children and adults and equally robust in response to taxonomic and thematic relations.

Specificity of taxonomic priming—The next step was to evaluate the specificity of the taxonomic priming effect by testing a different type of prime—those that involved perceptual but not semantic relations. Baseline-adjusted RTs in the perceptual condition categorized by

age and priming group appear in Figure 3. These data were tested via ANOVA, with age (6, 8, adult) and priming group (primed, unprimed) as between-subjects variables. Again there was a main effect for priming group, $F(1, 69) = 4.20, p = .05, f = .23$, but this time the primed group made significantly slower judgments than the unprimed group. Again a lack of age effect, $F(2, 69) = 1.30, p = .29$, suggested that both children and adults responded similarly, once adjusted for baseline RT.

Discussion

Semantic relations of both the taxonomic and thematic types primed the object decisions of children and adults by speeding their processing. This result is consistent with that of Brouwers and colleagues (2001), but it provides the added advantage of confirming equivalent effects of the taxonomic and thematic subtypes. Perceptual relations also primed object decisions in all age groups, but served to slow rather than hasten responses. This result parallels that of Flores d'Arcais and Schreuder (1987) who found differing effects of perceptual primes (e.g., *tennis racket-guitar*) and taxonomic primes (e.g., *accordion-guitar*) on adults' picture naming latencies. We conclude that, by age 6, children organize concepts in similar ways as adults and that their knowledge of taxonomic concepts runs deeper than appreciation of mere physical similarity. The lines of evidence follow for each conclusion.

Children and adults demonstrate a similar conceptual organization—Consistent with overall improvement in processing speed across childhood (Kail, 1990), 6-year-olds made slower decisions in the baseline condition than did 8-year-olds, who were slower still than adults. However, there were no age effects on degree of priming once RTs in the primed conditions were corrected for baseline. Apparent in Figures 2 and 3 were trends toward less dramatic differences between adult primed and unprimed groups than between child primed and unprimed groups; however, these interactions were not statistically significant. This is especially remarkable given that between-group differences in baseline RTs can exaggerate between-group differences in priming (Chapman, Chapman, Curran, & Miller, 1994). This null effect may be a function of sample size; however, when Brouwers et al. (2001) analyzed age effects on degree of priming (albeit with younger and older children rather than with children and adults), they also found that older participants were faster overall, but that age did not relate significantly to the degree of semantic priming.

We conclude that, for children as young as 6, taxonomic concepts exert top-down influences on their perception of objects, much as in adults, by propagation of the activation of semantic features that are germane to the target. This is not to say that the nature of the priming effect is equivalent in children and adults. Given the relatively long SOA used in the current study, it is likely that the adults' responses reflected not only automatic but also strategic processing of the primes (Neely, 1991). Furthermore, with a larger sample, the interaction between age and priming group may reach significance. We conclude that only children of 6 and 8 years demonstrate a similar pattern of priming as adults. The important implication is that they structure conceptual space similarly to adults. The next section is a more detailed discussion of the nature of the children's taxonomic concepts.

Six-year-olds represent true taxonomic relations—One corollary of the shift hypothesis is that children of 6 do not represent taxonomic relations. The current data constitute counterevidence. First, consider that, given an identical time course of prime and target presentation, perceptual primes interfered while taxonomic primes facilitated processing. The dissociation of taxonomic and perceptual primes suggests that the children's knowledge of relations binding object concepts into taxonomies was not reducible to common physical features. The children's taxonomic structures were conceptual, as opposed to merely perceptual, in nature.

Second, note that the taxonomic knowledge of the 6-year-olds was not limited to developmentally early types. Lucariello et al. (1992) have argued that early taxonomic relations are limited to slot fillers, types that, like thematic concepts, readily serve as constituents of event structures. Because the taxonomic stimulus set did not include items that received a high thematic association rating, the primes related to the targets by virtue of common taxonomy alone. Therefore, the current data argue against the hypothesis that the taxonomic knowledge of children younger than 7 is limited to slot-filler types. This may be true of very early development, but at age 6, the participants demonstrated more mature taxonomic concepts.

Finally, recall that taxonomic primes did not lead the 6-year-olds to improve the speed of object decisions at the expense of accuracy. Rather, they were quicker and more accurate in response to taxonomic primes. Eight-year-olds and adults, who were more accurate overall than the 6-year-olds, had little room to improve accuracy in response to taxonomic primes, but they were similar to the 6-year-olds in demonstrating no speed–accuracy tradeoffs in response to taxonomic primes (nor in response to any other prime types).

In summary, we conclude that 6-year-olds represent true taxonomic relations because their priming behavior in the taxonomic condition, manifested as a reduction in the time required to make an object decision, was not reducible to a low-level perceptual effect; it was not limited to relations between slot fillers; and it was not produced at the expense of accuracy.

Interpreting the null effect—One finding of Experiment 1 stands contrary to prediction. We expected the children, especially the 6-year-olds, to demonstrate a larger priming effect in response to thematic than to taxonomic relations. That these effects were instead highly similar might be taken as evidence against the shift hypothesis. However, we would be more comfortable in interpreting this null finding if we could demonstrate a thematic advantage with these same participants, using a task known to elicit such an advantage. One such task requires participants to describe the commonality between objects. For this task, a thematic to taxonomic shift occurring between the ages of 4 to 8 years has been consistently reported (Goldman & Levine, 1963; Lucariello et al., 1992; Scott et al., 1982, 1985). In Experiment 2, we administered this task to test the prediction that children who demonstrated equivalent automatic processing of thematic and taxonomic relations (in object priming) would still perform more accurately on thematic relations than on taxonomic relations in a more demanding task (the comparison task). Furthermore, we predicted a developmental progression such that the 6-year-olds would demonstrate a more dramatic performance difference between thematic and taxonomic relations than would the 8-year-olds. These predictions follow directly from an alternative to the shift hypothesis, the performance hypothesis.

Experiment 2

Experiment 2 was a probe of the children's knowledge of taxonomic and thematic relations. It was considered more demanding than the task used in Experiment 1 because it required conscious analysis and a verbal response.

Method

Participants—To aid interpretation of the null effects reported previously, the 29 children recruited for Experiment 2 were those who originally served as members of the primed group in Experiment 1.

Procedure—The children were given a notebook with a pair of objects pictured on each page. Again, to aid comparison to Experiment 1, the pairs were those that had been used in the taxonomic and thematic conditions of the object decision task. The children were asked to describe, “Why these things belong together” (after Walsh et al., 1993). The examiner

described how dogs and cats go together (“They’re both animals” and “They’re both pets”) and how dogs and bones go together (“Dogs like to chew on bones”) to illustrate the range of desired answers. To be credited, a taxonomic answer had to convey that the two objects were of a common sort. Therefore, answers containing category names or shared functions were counted as correct (e.g., “Planes and buses are both vehicles” or “Planes and buses are both things to ride in”), but answers involving schemata were not (e.g., “Planes and buses have fumes”). Thematic answers had to convey legitimate, salient schemata (e.g., “Apples grow on trees” and “Needles pull thread”) but not ad hoc or perceptual relations (e.g., “Apples and trees are both found outside” and “Needles and thread are both tiny”). This scoring procedure is consistent with that of Blaye and Bonthoux (2001). Point-to-point interrater agreement on response accuracy was 98%.

Results

Overall, the children performed with a high level of accuracy (Figure 4). This overall pattern varied with age and semantic relation type. A mixed-model ANOVA with age (6 and 8) as a between-subjects variable, semantic type (taxonomic, thematic) as a within-subject variable, and percent of responses correct as the dependent variable yielded a main effect for age, $F(1, 26) = 5.90, p = .02, f = .18$, and a main effect of semantic type, $F(1, 26) = 22.50, p = .00007, f = .46$. These main effects were qualified by an interaction, $F(1, 26) = 11.20, p = .002, f = .30$. As illustrated in Figure 4, the 6-year-olds were significantly more accurate in the thematic than in the taxonomic condition, $t(14) = 4.20, p = .0009$, but this performance gap did not reach significance for the 8-year-olds, $t(13) = 1.70, p = .1$.

Discussion

Given their strong performance, it is clear that the 6-year-olds were knowledgeable about both thematic and taxonomic relations. Nevertheless, these data reveal a shift between 6 and 8 years in the accessibility of taxonomic relations during tasks with a high cognitive–linguistic load, as predicted by the performance hypothesis. Similarly, Lucariello et al. (1992) and Scott et al. (1985) both found children to better describe thematic (complementary) relations than taxonomic (conventional) relations, with the older children performing stronger overall.

General Discussion

At ages 6 and 8, children have semantic systems that are organized according to both thematic and taxonomic relations. In the semantic-priming object decision task used in Experiment 1, the strength of these relations did not vary greatly relative to one another, as taxonomic priming was as strong as thematic priming, nor relative to development, as the degree of priming among 6-year-olds, 8-year-olds, and adults was similar. The advantage of the priming task for measuring semantic competence emerges when the results are compared with those of the offline task of Experiment 2. In that task, 6- and 8-year-olds were asked to reflect on and verbalize thematic and taxonomic relations. Here taxonomic relations were more challenging, and a developmental difference between 6- and 8-year-olds was clear. Combining the findings of Experiments 1 and 2, we conclude that (a) children as young as 6 represent both taxonomic and thematic relations, but (b) thematic relations are the more robustly represented of the two. These conclusions led us to reject the strong form of the thematic–taxonomic shift in favor of a weaker alternative, the performance hypothesis. Each of these conclusions is discussed in turn.

Taxonomic and Thematic Relations Structure Concepts From Age 6 Into Adulthood

One purpose of this study was to contribute to the debate on the thematic–taxonomic shift. We reasoned that a semantic-primed object decision task, a task that requires neither analytic processing nor lexical retrieval, would be an ideal test of the shift hypothesis in that it reduced

the possibility that semantic competence would be masked by cognitive/linguistic performance. This was the case as the task revealed that by age 6, children structure concepts both thematically and taxonomically. We conclude that there is not a shift reflecting a cognitive restructuring between the ages of 6 and 8 years (though this does not rule out a shift earlier in development). What we see at age 6 is a taxonomic system that can be tapped via automatic processing, but that is not as robust in the face of conscious reflection and verbalization. In contrast, the 8-year-olds were well able to draw upon taxonomic relations in both tasks.

Knowledge of Taxonomic Concepts Becomes More Robust Between Ages 6 and 8

Given the priming data, it is clear that these 6-year-olds appreciated taxonomic concepts; why then did they have difficulty describing them? The interpretation that follows from the performance hypothesis is one of task demand. Ample evidence from the literature on learning and memory in general (e.g., Neath, 1998, for a review) and language learning and memory in particular (e.g., Laufer & Goldstein, 2004) demonstrates that recognition is typically easier than recall. The priming task in Experiment 1 required only that children recognize the objects and their relations, whereas the description task in Experiment 2 required them to verbally recall those relations. Furthermore, Experiment 1, being online, was more likely to elicit fast, automatic responses, whereas Experiment 2, being offline, encouraged conscious analysis and reflection.

Taxonomic concepts are generally more abstract than thematic concepts (Scott et al., 1985), particularly when, as in the current study, those taxonomic categories represent superordinate rather than basic relations (Markman, 1989). Whereas taxonomic concepts are represented by age 6 (hence Experiment 1 results), they have become more robustly represented by age 8 (hence Experiment 2 results). Harder tasks, such as the recall task in Experiment 2, require more robust levels of knowledge to support performance (Laufer & Goldstein, 2004). Unlike the 6-year-olds, the 8-year-olds were able to maintain good performance when describing taxonomic relations because they had developed a more robust representation of these relations.

Developmental time is one obvious factor contributing to the superior performance of the 8-year-olds, but another likely factor is educational experience. With 2 more years of schooling, 8-year-olds are more familiar with tasks that require and promote taxonomic comparisons than are 6-year-olds. Exercises involving comparison and contrast or, more specifically, synonyms and antonyms are common in the early school years, and such tasks have been shown to promote taxonomic classification in adults (see Experiments 7 and 8, Lin & Murphy, 2001). Moreover, exercises involving verbal definitions may increase knowledge of taxonomies because the Aristotelian form of definitions taught in educational settings requires superordinate category labels. We hypothesize that, with development and exposure to educational environments, children's representations of taxonomic concepts become more robust and less prone to performance declines. Though it is difficult to disentangle the two effects, studies of adults with no formal education have revealed low performance on tasks requiring reflection on taxonomic relations (Luria, 1976), suggesting that schooling does play, at least in part, an independent role.

Conclusion

In summary, semantic relations primed object decisions of 6- and 8-year-old children and adults. Although overall the adults were quicker to respond than the children, degree of priming did not reliably differentiate the age groups. For both 6- and 8-year-olds as well as adults, thematic and taxonomic relations produced similar priming effects despite the 6-year-olds' more notable difficulty in describing taxonomic relations in the offline probe. Differential priming effects in taxonomic and perceptual conditions suggested that the taxonomic effects were not reducible to shared physical features between members of a taxonomy. We conclude

that children as young as 6 years old represent true taxonomic concepts, and that these concepts exert top-down influences on their perception of objects, much as in adults, by propagation of the activation of semantic features that are germane to the target. The 6-year-olds' relative difficulty in reporting taxonomic relations suggests that, compared with thematic relations, taxonomic relations are more vulnerable to task demands as predicted by the performance hypothesis.

Acknowledgements

We thank the participants for their time and effort, as well as James Booth, Nina Capone, Kristy Grohne Reilly, Swathi Kiran, Robyn Newman, Renée Reilly, Katharina Rohlfing, Li Sheng, and Sandy Waxman for their helpful insights. Dedre Gentner graciously provided stimuli for the perceptual condition. The second author was supported by the National Institute on Deafness and Other Communication Disorders (Grants R29 DC 03698 and 2 R01 DC003698-06).

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Appendix A

Stimuli

Thematic	Real Object Stimuli for the Primed Group		Unrelated
	Taxonomic	Perceptual	
Prime–Target	Prime–Target	Prime–Target	Prime–Target
apple–tree	cheese– egg	axe–toothbrush	barrel–lightning
bread–toaster	eye–foot	candy cane–umbrella	bottle–radio
candle– cake	hammer–saw	cap–igloo	clothespin– canoe
door–latch	hat–belt	cd–plate	frame–cup
iron–shirt	kite–ball	drum–bucket	pen–mountain
key–lock	piano– guitar	feather–banana	shell–penny
needle–thread	plane–bus	fork–broom	sun– wagon
pot–stove	potato– carrot	lamp–mushroom	sword–book
road– car	stool– chair	lemon–football	tractor–bow

Note. The unprimed group received only the targets of the prime–target pairs.

Examples of Pictures Used as Stimuli

Taxonomic

Thematic

Perceptual

Nonobject

Appendix B**Priming procedure**

Format of a Trial for the Primed Group

Priming Picture	Interstimulus Interval	Target Picture	Intertrial Interval

500 ms	500 ms		500 ms

Begin measuring RT

End measurement with button-press response

Format of a Trial for the Unprimed Group

Target Picture	Intertrial Interval

	500 ms

Begin measuring RT

End measurement with button-press response

Figure 1.

Accuracy of object decisions according to age, priming group, and condition. Error bars reflect standard error of the mean.

Figure 2.
The effect of semantic primes on object decision. Error bars reflect standard error of the mean.

Figure 3.
The effect of perceptual primes on object decision. Error bars reflect standard error of the mean.

Figure 4. Accuracy of descriptions of taxonomic and thematic relations. Error bars reflect standard error of the mean.

Table 1
Data cleaning by type and age in primed and unprimed groups.

	Primed group		Unprimed group
		6-year-olds	
Outliers	1.68% (17/1008)		2.38% (15/630)
Perception errors	2.82% (28/991)		8.30% (51/615)
Object decision errors	3.94% (38/963)		7.90% (45/564)
		8-year-olds	
Outliers	0.93% (10/1080)		0.91% (7/770)
Perception errors	2.24% (24/1070)		4.06% (31/763)
Object decision errors	3.63% (38/1046)		5.00% (37/732)
		Adults	
Outliers	0.46% (4/864)		0.64% (5/770)
Object decision errors	4.53% (39/860)		3.92% (30/765)

Table 2

Mean accuracy of response (and standard deviations in parentheses) by condition and age in primed and unprimed groups.

	Primed group	Unprimed group
		6-year-olds
Taxonomic	94.5 (7.15)	75.6 (14.30)
Thematic	95.3 (5.60)	86.6 (9.20)
Perceptual	91.4 (8.80)	85.3 (14.60)
Unrelated	80.4 (12.00)	92.1 (9.10)
		8-year-olds
Taxonomic	96.3 (5.40)	87.0 (6.60)
Thematic	97.1 (5.00)	91.0 (6.60)
Perceptual	97.8 (4.60)	87.0 (12.80)
Unrelated	90.1 (6.20)	93.8 (9.80)
		Adults
Taxonomic	91.2 (10.40)	93.0 (7.40)
Thematic	97.1 (5.00)	95.0 (7.60)
Perceptual	94.9 (5.70)	98.0 (4.40)
Unrelated	99.3 (2.80)	94.0 (7.60)

Table 3

Means (and standard deviations in parentheses) of reaction times in the unrelated condition by age and priming group.

	Primed group	Unprimed group
6-year-olds	1,814.3 (456.0)	1,519.2 (321.6)
8-year-olds	1,360.8 (428.0)	1,317.3 (241.5)
Adults	757.2 (201.6)	749.5 (158.2)